MOLDED FOAM PLUGS, PLUG SYSTEMS AND METHODS OF USING SAME

BACKGROUND

[0001] The present invention relates generally to subterranean well construction, and more particularly to plugs, plug systems, and methods for using these plugs and systems in subterranean wells.

[0002] Cementing operations may be conducted in a subterranean formation for many reasons. For instance, after (or, in some cases, during) the drilling of a well bore within a subterranean formation, pipe strings such as casings and liners are often cemented in the well bore. This usually occurs by pumping a cement composition into an annular space between the interior wall of the well bore and the exterior surface of the pipe string disposed therein. Generally, the cement composition is pumped down into the well bore through the pipe string, and up into the annular space. Prior to the placement of the cement composition into the well bore, the well bore is usually full of fluid, *e.g.*, a drilling mud or fluid. Oftentimes, an apparatus known as a cementing plug may be employed and placed in the fluid ahead of the cement composition to separate the cement composition from the drilling fluid as the cement slurry is placed in the well bore. The cementing plug also wipes drilling fluid from the inner surface of the pipe string as it travels through the pipe string, thereby preventing contamination of the cement slurry by the drilling fluid as it is pumped downhole. Once placed in the annular space, the cement composition is permitted to set therein, thereby forming an annular sheath of hardened substantially impermeable cement therein that substantially supports and positions the pipe string in the well bore and bonds the exterior surface of the pipe string to the interior wall of the well bore.

[0003] In some circumstances, a pipe string will be placed within the well bore by a process comprising the attachment of the pipe string to a tool (often referred to as a "casing hanger and run-in tool" or a "work string") which may be manipulated within the well bore to suspend the pipe string in a desired location. In addition to the pipe string, a sub-surface release cementing plug system comprising a plurality of cementing plugs may also be attached to the casing hanger and run-in tool. Such cementing plugs may be selectively released from the run-in tool at desired times during the cementing process. Additionally, a check valve, typically called a float valve, will be installed near the bottom of the pipe string. The float valve may permit the flow of fluids through the bottom of the pipe string into the annulus, but not the reverse. A cementing plug will not pass through the float valve.

[0004] When a first cementing plug (often called a "bottom plug") is deployed from a sub-surface release cementing plug system and arrives at the float valve, fluid flow through the float valve is stopped. Continued pumping results in a pressure increase in the fluids in the pipe string, which indicates that the leading edge of the cement composition has reached the float valve. Operations personnel then increase the pump pressure to rupture a rupturable member, within the bottom plug. Said rupturable member may be in the form of a pressure sensitive disc, rupturable elastomeric diaphragm, or detachable plug (stopper) portion which may or may not remain contained within the bottom plug. After the rupturable member has failed, the cement composition flows through the bottom plug, float valve and into the annulus. When the top plug contacts the bottom plug which had previously contacted the float valve, fluid flow is again interrupted, and the resulting pressure increase indicates that all of the cement composition has passed through the float valve. It is important that all of the desired cement composition be pumped into the annulus from the pipe string. If not, the cement remaining in the pipe string will

have to be drilled out before any further activities can take place. Furthermore, the annulus might not be properly filled with cement, and undesirable formation-fluid migration or failure of the pipe string may result. On the other hand, if the cement is overdisplaced, a lower portion of the annulus might not be properly filled with cement, and undesirable formation-fluid migration or failure of the pipe string could result. Overdisplacement of the cement is considered a worse problem than underdisplacement, as it can be more difficult to correct.

[0005] Conventional cementing plugs are formed with wiper fins on their exterior surface, which function to wipe the pipe string as they travel downhole. Conventional cementing plugs used to wipe large diameter casing strings (18-5/8 and larger) are by their very nature expensive to make, both heavy and bulky to handle, and require additional time to drill out due to the sheer volume of drillable materials to be removed. Under some conditions it may be advantageous to the well operator to run casing strings consisting of two or more pipe sizes, with the larger pipe size being at the shallowest depth and progressively tapering to the minimum pipe size. These casing configurations are typically known as "tapered strings" and require specially designed cementing plugs to wipe the different pipe diameters involved.

[0006] Figure 1 illustrates a typical cementing plug used to wipe a tapered string consisting of two different pipe sizes. Especially when three more pipe sizes are to be wiped, the plugs become overly long to fit in conventional plug containers and due to the long, flexible wiper segments used to wipe the larger pipe sizes the plugs may be generally unbalanced, or unstable, such that they may not clean the pipe wall and separate fluids with the desired efficiency. As can be seen from this drawing, the cementing plug has a complex design. In particular, it is formed of two or more distinct body sections that have been joined together end to end. The front body section contains a set of wiper fins that project radially outward a first

diameter. The rear body section contains a separate set of wiper fins that project radially outward a second diameter, which is greater than the first diameter. The wiper fins of the front body section operate to wipe the section of the pipe string having the smallest diameter, which is the section of the pipe string that penetrates deepest into the well bore. The wiper fins of the rear body section operate to wipe the section(s) of the pipe string having the greatest diameter(s), which is the section of the pipe string that penetrates into the shallow section of the well bore. Both body sections are machined so that they can be threadably engaged. Accordingly, conventional cementing plugs are fairly complex devices that are relatively time-consuming and thus expensive to manufacture, difficult to use, and are more costly to drill out due to the increased plug length and/or material content.

[0007] In addition, cementing plugs may be required to pass through internal restrictions designed into special tools which may be incorporated into the pipe string, such as the seats in a plug operated multiple stage cementing device. The specially designed cementing plugs required to pass through these types of internal restrictions must both effectively wipe the casing ID and pass through the internal restrictions with minimal pressure increase to avoid prematurely activating the tool. In these instances, it is generally impossible to place the special devices in tapered strings unless the device is located in the largest pipe size due to the increased pressure that would otherwise be required to force the mass of the larger wiper segments through the restrictions.

[0008] Thus, there is a need for a new type of cementing plug capable of wiping multiple pipe diameters and/or easily passing through small internal restrictions that is more efficient, less costly, more user friendly, and be at least partially comprised of easily removed materials.

SUMMARY

[0009] The present invention relates generally to subterranean well construction, and more particularly, to cementing plugs, plug systems, and methods for using these plugs and systems in subterranean wells.

[0010] In one embodiment, the present invention is directed to an improved plug for separating successively introduced fluids into a wellbore, in particular a casing string. The plug comprises a cylindrically-shaped inner mandrel that has a hollow inner passage through which fluids may pass and an outer elastomeric foam sleeve secured thereto. The outer elastomeric foam sleeve may be generally cylindrically shaped or contain a series of ribs or similar geometric shapes forming its outer longitudinal profile. The plug has a nose profile formed at the lower end of the inner mandrel and an internal upset formed at the upper end having a bore larger than the ID of the inner mandrel at that end. A recess is also formed within the nose profile. In one embodiment, a high pressure disc is secured within the recess formed in the upper end. In another embodiment, a rupturable member is secured within the recess formed in the upper end.

[0011] In another embodiment, the elastomeric foam outer body may be attached to a solid inner mandrel comprising a nose section designed to perform a specific function, such as seat and/or seal into a special profile such as a first stage baffle/baffle adapter typically used in multiple stage cementing operations using plug operated multiple stage cementing devices. As described below, the inner mandrel may take many different forms.

[0012] In another embodiment, the present invention is directed to a plug system for separating fluids successively introduced into a passage. The plug system comprises an assembly of at least two plugs of the type described immediately above. In one embodiment,

two plugs linearly aligned in a top and bottom configuration are provided. The plugs are placed into the casing string with the nose portions facing down. The top plug is formed with the high pressure disk and the bottom plug is formed with the rupturable member, which mates with the nose portion of the top plug. The plug system according to the present invention may further comprise a float valve, which is designed to be installed inside the casing string at the end disposed at the bottom of the well bore. The recess in the nose of the inner mandrel of the bottom plug is fitted with a flat face seal ring that is adapted to mate with, and seal against, the top face of the float valve.

[0013] In yet another embodiment, the present invention is directed to a method of separating fluids successively introduced into a subterranean well bore. The method comprises the steps of suspending an assembly comprising a plurality of plugs within a casing string, wherein at least one of the plugs comprises an inner mandrel and an outer elastomeric foam sleeve secured thereto; introducing a first fluid into the well bore through the casing string; introducing a second fluid into the well bore behind the first fluid such that an interface between the two fluids is formed; and deploying at least one plug within the casing string at the interface of the first and second fluids. The assembly preferably includes a top and bottom plug of the type described immediately above.

[0014] In one embodiment, the first fluid is a drilling fluid, the second fluid is a cement slurry and the bottom plug wipes the inside of the casing string clean of the drilling fluid as it travels down the casing string. The cement slurry is pumped downhole until the bottom plug lands against the uppermost float valve, the rupturable member fails at which point the cement slurry is displaced through the bottom plug, float valve(s), casing shoe and into the annulus formed between the casing string and the inside of the well bore. The top plug is

deployed behind the cement slurry and wipes the inside of the casing string clean of the cement slurry as it travels downhole. Once the top plug engages the bottom plug at the bottom of the well bore the only cement left inside the casing is between the upper float valve and the casing shoe. The top plug prevents the cement slurry from being overdisplaced. After the cement slurry has cured, the top and bottom plugs and the float valve may be drilled out of the casing string, if required.

[0015] The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments, which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] A more complete understanding of the present disclosure and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawing, wherein:

[0017] Figure 1 is an elongational cross-sectional view of a prior art cementing plug.

[0018] Figure 2 is an elongational cross-sectional view of a top plug of a plug system in accordance with the present invention.

[0019] Figure 3 an elongational cross-sectional view of a bottom plug of a plug system in accordance with the present invention.

[0020] Figure 4 illustrates a plug in accordance with the present invention as it travels downhole through the inside of a telescoping casing string.

[0021] Figure 5 illustrates the deformation of the outer foam sleeve of the plug of Figure 4 as it passes into a restriction in the casing string.

[0022] Figure 6 illustrates the engagement of the bottom plug of a two plug system with a float valve in accordance with the present invention.

[0023] Figure 7 illustrates engagement of the top plug with the bottom plug of the two plug system shown in Figure 6.

[0024] Figure 8 is an elongational cross-sectional view of an alternate embodiment of a plug in accordance with the present invention.

[0025] Figure 9 is another embodiment of a plug in accordance with the present invention similar to that of Figure 8, except that its outer sleeve is formed with ribs.

[0026] Figure 10 is an elongational cross-sectional view of another alternate embodiment of a plug in accordance with the present invention.

[0027] Figure 11 is another embodiment of a plug in accordance with the present invention similar to that of Figure 10, except that its outer sleeve is formed with ribs.

[0028] Figure 12 is an elongational cross-sectional view of an alternate embodiment of a plug system in accordance with the present invention.

[0029] Figure 13 is another embodiment of a plug system in accordance with the present invention similar to that of Figure 12, except that the outer sleeves of the plugs are formed with ribs.

[0030] Figure 14 is an elongational cross-sectional view of an yet another alternate embodiment of a plug system in accordance with the present invention.

[0031] Figure 15 is another embodiment of a plug system in accordance with the present invention similar to that of Figure 14, except that the outer sleeves of the plugs are formed with ribs.

DESCRIPTION

[0032] The details of the present invention will now be described with reference to the figures. Turning to Figure 2, a plug in accordance with the present invention is shown generally by reference numeral 10. The plug 10 is formed of two basic components, an inner mandrel 12 and an outer sleeve 14.

[0033] The inner mandrel 12 is preferably generally cylindrical in shape and formed of a suitable drillable material such as, but not limited to, aluminum, high strength plastic, glass fiber composite, and other materials having similar properties. The inner mandrel 12 preferably has a hollow cylindrically-shaped interior region through which drilling muds and fluids, cementing slurries and the like may flow uninhibited. The inner mandrel 12 could also be made of a solid elastomeric material. The inner mandrel 12 also has a nose portion 16 formed at one of its ends. Preferably, the combined length of the inner mandrel 12 and nose portion 16 has a minimum length equal to the largest pipe OD that the plug is designed to wipe. This length-to-pipe diameter relationship is necessary to prevent the plugs from inverting in the largest pipe diameter. The foam outer body may or may not encompass the entire mandrel length.

[0034] The nose 16 may be disc-shaped. In one preferred certain embodiment, the nose 16 is removably attached to the inner mandrel 12 so that different noses may be attached for different applications. There is a recess 18 formed within the lower end of the inner mandrel 12. An elastomeric flat face seal ring 19 is disposed within the recess 18, which is adapted to mate with the top end of another plug and/or the face of a float valve or other similar device. In an alternate embodiment, the entire nose 16 may be formed of rubber.

[0035] The inner mandrel 12 also has a recess 20 formed in the upper end. The recess 20 is adapted to receive either a high pressure disc 22, as shown in Figure 2, or a

rupturable member such as a rupture disc 24, as shown in Figure 3. As those of ordinary skill in the art will recognize, there are many other ways in which the discs 22 and 24 can be attached to the upper end of the inner mandrel 12. As but one example, they could be formed into a cap that slips over and seals on the end of the mandrel.. As those of ordinary skill in the art will further recognize, the overall size of the plug 10 and thus the diameter of the inner mandrel 12 will be a function of the diameter of the pipe into which it will be inserted as well as the particular application that the plug will be used in.

[0036] The high pressure disc 22 is designed to withstand high pressures and preferably will resist failing when exposed to pressures up to approximately 9,000 psi. Of course, higher pressure devices may be used in its place. In one preferred application, the high pressure disc 22 is used to bridge the top plug mandrel ID with a high pressure bridge. The entire top plug stops fluid flow upon landing upon a suitable seat. The high pressure disc 22 can either be cemented into the recess 20 using a two-part epoxy or other similar adhesive known in the art; integrally formed into the body of the inner mandrel 12; or otherwise secured to the inner mandrel by means known in the art.

[0037] The rupture disc 24 is designed to fail at a predetermined pressure, *e.g.*; approximately 750 psi and above. Of course, the rupture disc 24 can be designed to fail at any desired pressure. The rupture disc 24 can either be cemented into the recess 20 using a two-part epoxy or other similar adhesive known in the art; integrally formed into the body of the inner mandrel 12; or otherwise secured to the inner mandrel by means known in the art.

[0038] The outer sleeve 14 is preferably generally cylindrical or rib shaped and formed of a compressible elastomeric foam. It is preferably formed of an open cell polyurethane foam. However, as those of ordinary skill in the art will appreciate, other foamable elastomers

may be used instead. The outer sleeve 14 is coaxially disposed around the outer surface of the inner mandrel 12. The outer sleeve 14 is preferably molded to the inner mandrel 12 by any suitable molding process, such as injection molding, cold pour molding, or other similar known process.

[0039] Figures 8 – 11 illustrate additional embodiments of the plug 10 in accordance with the present invention. Figure 8 illustrates an alternate embodiment of the plug (210), wherein the inner mandrel 212 is formed of a solid material, *i.e.*, it is not formed with an internal flow passage. Furthermore, in this embodiment the nose 216 is integrally formed with the inner mandrel 212. The outer sleeve 214 is similar to outer sleeve 14 in that it is preferably formed of a foam or similar material and generally cylindrical in shape. Figure 9 illustrates an alternate embodiment of the plug 210' shown in Figure 8. The only difference in this embodiment is that the outer sleeve 214' contains a series of ribs 221.

[0040] Figure 10 illustrates an alternate embodiment of the plug (310), wherein the inner mandrel 312 is formed of a tubular member having a nose 316 integrally formed within its lower end and a recess 320 formed within its upper end. A high pressure disc or rupturable member such as a rupture disc (not shown) can be inserted within the recess 320, as described above. The outer sleeve 314 is similar to outer sleeve 14 in that it is preferably formed of a foam or similar material and generally cylindrical in shape. Figure 11 illustrates an alternate embodiment of the plug 310' shown in Figure 10. The only difference in this embodiment is that the outer sleeve 314' contains a series of ribs 321.

[0041] Referring now to Figures 4 and 5, the flow of the plug 10 inside of a casing string 50 is illustrated. In particular, Figure 4 shows plug 10 traveling through the large diameter section 52 of the casing string 50. As can be seen in that figure, the outer foam sleeve

14 is sized so as to come into contact with the inside surface of the large diameter section 52 of the casing string 50. Indeed, the outer foam sleeve 14 of plug 10 wipes the inside surface of the large diameter section 52 of the casing string 50 clean as it travels through that section of the casing string. Figure 5 illustrates how the outer foam sleeve 14 of plug 10 conforms to the inner surface of the casing string 50 as it encounters a restriction 54, which is where the inside of the casing string narrows in its diameter. The compressible nature of the foam forming the outer sleeve 14 enables the plug 10 to conform to the changing diameter within the casing string 50. Complex devices of the type shown in Figure 1, which employ multi-diameter fins, were previously needed to wipe clean the inner surface of a multi-diameter casing string.

[0042] A simple plug system in accordance with the present invention is shown generally in Figure 6 by reference numeral 100. It comprises plug 110, which is a plug of the type shown in Figure 3, *i.e.*, a plug that has a rupture disc 24 at the upper end. However, as those of ordinary skill in the art will recognize, any of the above described embodiments of the plug may be employed. The plug system 100 further comprises a float valve 112, which is mounted within the casing string 50 proximate the bottom of the well bore. The nose 16 of the plug 110 is designed to mate with the top face of the float valve 112.

[0043] The float valve 112 comprises a collar valve housing encased in cement 114 and a linearly moveable plunger 116. The plunger 116 includes a central shaft, which has a disc attached to it at one end and a partially ball-shaped member attached to it at the other end. It also includes a spring, which biases the plunger 116 into a position where the ball-shaped member seats itself into a partially spherically-shaped recess formed within the collar. The plug 110 is designed to seat against the top face of the float valve 112. The float valve 112 is a one way check valve, and therefore prevents fluid below the valve from flowing up hole.

[0044] Fluid flows down hole through the float valve 112 as follows. Once the downward fluid pressure exceeds the threshold of the rupture disc of the plug 110, the fluid flows through the hollow region of the plug and acts on the plunger 116 and ball-shaped member. The fluid pressure then pushes the plunger 116 downward, which in turn unseats the partially ball-shaped member from the partially spherical recess, which in turn allows the fluid to flow through the float valve 112. As those of ordinary skill in the art will appreciate, the exact design of the float valve 112 is not critical to the present invention. Other equivalently functioning devices may be employed in its place.

[0045] The plug system 100 may include a second plug 118, which is formed with a high pressure disc at its upper end. The plug 118 is designed to engage and mate with plug 110. More particularly, the upper end of plug 110 mates with the nose portion of plug 118. For ease of reference, plug 110 will be referred to as the bottom plug and plug 118 will be referred to as the top plug. As those of ordinary skill in the art will appreciate, plug system 100 may include any number of plugs. At least two plugs are generally required, however, for most cementing applications.

[0046] A method of separating fluids successively introduced into a subterranean well bore according to the present invention will now be described. A plug assembly containing a top and bottom plug are run in a casing string to the desired depth and suspended therein. A first fluid, generally a drilling mud used to drill the hole, is introduced into the well bore through casing string 50. Next, a second fluid, generally comprising a cement slurry, is introduced into the well bore behind the first fluid such that an interface between the two fluids is formed. Simultaneously, the bottom plug 110 is released from the assembly and deployed within the casing string at the interface of the first and second fluids. As the bottom plug 110 travels

downhole between the first and second fluids, it wipes the inside of the casing string 50 removing it of any residue left behind by the first fluid. Once the bottom plug 110 reaches the bottom of the casing string 50, it seats into the float valve 112 in the manner described above.

[0047] The slurry is continuously pumped into the casing string 50 until the desired amount is reached. The volume of slurry required is a function of drilled hole size, casing OD and the amount of fillup that is desired in the annulus. It is quite common for the bottom plug 110 still to be traveling down the pipe when the desired volume of cement is pumped and the top plug 118 released. Both plugs with the cement (and spacer fluid if pumped on top of the bottom plug) trapped in between are displaced by a third fluid, which can be, but does not have to be, the same as the first fluid used to circulate the hole initially, until the bottom plug 110 lands and the rupture disk 24 (or other rupturable member) fails. Displacement continues until such time as the top plug 118 lands on top of the bottom plug 110 (as shown in Figure 7), or float valve 112 in a top plug only application) wherein a pressure increase signals that the top plug has landed and final displacement is finished.

[0048] As the top plug 118 travels downhole behind the second fluid, it also wipes the inside of the casing string 50 removing it of any residue left behind by the second fluid. Once the top plug 118 reaches the bottom of the casing string 50, it seats into the bottom plug 110 in the manner described above and shown in Figure 7. The high pressure disc 22 of the top plug 118 is designed to preclude any further displacement of the second fluid into the well bore. Indeed, the timing of the release of the bottom and top plugs 110, 118, respectively, as well as the monitoring of the precise amount of the second fluid being pumped into the casing string 50 are important in avoiding under and overdisplacement of the second fluid. This is

particularly important wherein the second fluid is a cementing slurry used to cement the casing string to the inside of the well bore.

[0049] Figure 12 shows two alternate plugs, top plug 410 and bottom plug 510, which together form alternate plug system 400. Top plug 410 is formed with a solid inner mandrel 412, which has a threaded lower end. A taper-shaped nose 416 attaches to the threaded lower end of the inner mandrel 412. However, as those of ordinary skill in the art will appreciate, the nose 416 can take any desired form and may be integrally formed with the inner mandrel 412. The outer sleeve 414 is similar to outer sleeve 14 in that it is generally cylindrically shaped and formed of a foam or other similar material.

[0050] The bottom plug 510 is formed with a generally tubular-shaped inner mandrel 512, which has a hollow interior for channeling fluids. The bottom plug 510 has a funnel-shaped tapered upper end adapted for engagement with the taper-shaped nose 416 of the top plug 410. The outer sleeve 514 is identical to outer sleeve 414 of the top plug 410. A nose 516 is integrally formed at the lower end of inner mandrel 512. A flow stopper plug 524 is temporarily secured to the nose 516 with one or more shear pins or other securing means. The flow stopper plug 524 is formed of a high strength thermoplastic or other similar material. As those of ordinary skill in the art will appreciate, the nose 516 may be removable. Furthermore, as those of ordinary skill in the art will appreciate, the release pressure of the flow stopper plug 524 may be adjustable.

[0051] Figure 13 illustrates an alternate embodiment of the plugs 410' and 510' shown in Figure 12. The only difference in this embodiment is that the outer sleeves 414' and 514' contain a series of ribs 421 and 521, respectively.

[0052] Figure 14 illustrates another embodiment of a plug system (600). Plug system 600 includes a top plug 610 and a bottom plug 710. The top plug 610 includes a generally tubular-shaped inner mandrel 612 having a taper-shaped nose 616 integrally formed at its lower end. The inner mandrel 612 is simply open at its upper end. As a consequence of its tubular design the inner mandrel has an internal flow channel, through which fluids may travel. Holes are formed in the nose 616 for inserting pins, which attach a flow stopper plug 670 to the internal flow channel of the plug 610. The flow stopper plug 670 is preferably formed of a high strength thermoplastic material and is designed to stop the flow of fluids through the internal flow channel. The number and strength of the pins holding the flow stopper plug 670 in place within the internal flow channel are selected so that the flow stopper plug 670 is forced out of the plug 610 at the desired pressure, which is dependent upon the particular application. A pair of elastomeric rings 672 are also provided to seal the flow stopper plug 670 to the inside wall of the internal flow channel, so that no fluid is allowed to seep past the flow stopper plug 670. The outer sleeve 614 is similar to outer sleeve 14 in that it is generally cylindrically shaped and formed of a foam or other similar material.

[0053] Bottom plug 710 includes an inner mandrel 712, which is generally tubular in shape having an internal flow channel, through which fluids may pass. The bottom plug 710 further includes a nose 716, which is generally taper-shaped and integrally formed with the inner mandrel 712 at its lower end. Holes are formed in the nose 716 for inserting pins, which attach a flow stopper plug 770 to the internal flow channel of the plug 710. The flow stopper plug 770 is preferably formed of a high strength thermoplastic material and is designed to stop the flow of fluids through the internal flow channel. The number and strength of the pins holding the flow stopper plug 770 in place within the internal flow channel are selected so that

the flow stopper plug 770 is forced out of the plug 710 at the desired pressure, which is dependent upon the particular application. An elastomeric ring 772 is also provided to seal the flow stopper plug 770 to the inside wall of the internal flow channel, so that no fluid is allowed to seep past the flow stopper plug 770. The bottom plug 710 has a funnel-shaped tapered upper end 774 adapted for engagement with the taper-shaped nose 616 of the top plug 610. The outer sleeve 714 is similar to outer sleeve 14 in that it is generally cylindrically shaped and formed of a foam or other similar material.

[0054] Figure 15 illustrates an alternate embodiment of the plugs 610 and 710 shown in Figure 12. The only difference in this embodiment is that the outer sleeves 614' and 714' of plugs 610' and 710' comprise a plurality of ribs 621 and 721, respectively.

[0055] The function, operation and advantages of the plug systems 600 and 600' illustrated in Figures 14 and 15 over conventional plug systems will now be described. As can be seen in Figures 14 and 15, the bottom plug 710, 710' is equipped with a sealing nose, which optionally may incorporate a latch down feature, and which may optionally be formed as an integral part of the bottom plug mandrel. The bottom plug 710, 710' is capable of being pumped down into a baffle profile (not shown) located above the upper most float valve assembly. The nose 716, 716' seals against the minimum ID of the baffle profile and resists further downward movement. Both of the profiles of the bottom plug nose 716, 716' and the baffle (not shown) are designed such that they will be capable of sustaining high pressure loads applied from above at high temperatures. Upon landing in the baffle profile, increased pressure will shear the rupturable member(s) retaining the plug 770, 770' in the nose of the bottom plug 710, 710', thereby allowing circulation to continue. A catching device located above the top float valve

(not shown) would be provided to catch the nose plug to keep the plug from interfering with the float valves.

[0056] After displacing the top plug 610, 610', with its tapered nose piece 616, 616', to a shut-off against the funnel shaped seat profile built into the top of the bottom plug mandrel 712, 712', further application of pressure will shear the plug pinned in the ID of the top plug mandrel 612, 612'. As the major ID's of both the top and bottom plug mandrels will be the same, the plug 670, 670' in the top plug 610, 610' will, after shearing free, continue to pass, in sealing engagement, through the major ID of the bottom plug mandrel 712, 712' until it is restrained by the internal restriction indicated near the lower end of the bottom plug nose 716, 716'. At this point, the only components that will be subjected to high pressure testing are the baffle profile, the bottom plug nose 716, 716', and the nose plug 616, 616' from the top plug 610, 610', no further loading will be imposed on either the top or bottom plug mandrels, 612, 612'; 712, 712', respectively. The only strength requirements for the bottom plug mandrel 712, 712', including the plug seat built into its top, is that it be strong enough to resist the forces imposed by pressuring up against the top plug 610, 610' to shear out its nose 616, 616'. The top plug mandrel 612, 612' has no special strength requirements other than the nose 616, 616' be capable of supporting the loads imposed in shearing out its nose plug 670, 670'. The nose plug 770, 770' shear pinned inside the bottom plug mandrel 712, 712' may be pinned to shear at a pressure valve that makes sense in view of job conditions. The plug 670, 670' shear pinned in the nose 616, 616' of the top plug 610, 610' also may be pinned to an appropriate value as the nose plug will remain pressure balanced until such time as the top plug is landed.

[0057] As those of ordinary skill in the art should recognize, the inner mandrels 612, 612' and 712, 712' of the plugs 610, 610' and 710, 710' need only be strong enough to resist

the forces/loads imposed to land the plugs 610, 610' and 710, 710' and release the nose plugs 670, 670' from the top plugs 610, 610', as discussed in the preceding paragraph.

[0058] While the use of the cementing plugs of the present invention in sub-surface release applications has been described, other embodiments of the present invention may advantageously employ these cementing plugs as conventional surface-release plugs and or as subsurface released plugs as well.

[0059] Therefore, the present invention is well-adapted to carry out the objects and attain the ends and advantages mentioned as well as those which are inherent therein. While the invention has been depicted, described, and is defined by reference to exemplary embodiments of the invention, such a reference does not imply a limitation on the invention, and no such limitation is to be inferred. The invention is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those ordinarily skilled in the pertinent arts and having the benefit of this disclosure. The depicted and described embodiments of the invention are exemplary only, and are not exhaustive of the scope of the invention. Consequently, the invention is intended to be limited only by the spirit and scope of the appended claims, giving full cognizance to equivalents in all respects.